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UNITED STATES DEPARTMENT OF AGRICULTURE

U.S. SOIL CONSERVATION SERVICE

WASHINGTON, D. C.

H. H. BENNETT, CHIEF

## ADVANCE REPORT

on the

# SEDIMENTATION SURVEY OF OTTAWA COUNTY STATE LAKE BENNINGTON, KANSAS

March 23 to April 13, 1937

by

Elliott M. Flaxman and Leland H. Barnes

In cooperation with

Kansas Agricultural Experiment Station  
Manhattan, Kansas  
L. E. Call, Director

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Washington, D. C.

Sedimentation Studies

Division of Research

SCS-SS-18

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ADVANCE REPORT ON THE  
SEDIMENTATION SURVEY OF OTTAWA COUNTY STATE LAKE  
BENNINGTON, KANSAS

GENERAL INFORMATION

Location (fig. 1):

State: Kansas.

County: Ottawa, Secs. 5, 8, 9, T. 11 S., R. 2 W.

Longitude 97° 34' W and Latitude 39° 6' N.

Distance and direction from nearest city: 8 miles east of Minneapolis; 4.5 miles north and 1.3 mile east from Bennington, Kans.

Drainage and backwater: The dam is on Sand Creek, an intermittent stream which heads in the maturely dissected Smoky Hills upland of north-central Kansas and flows south-southwest to join the Solomon River 6 miles below the dam. Water is impounded on both the east and west forks.

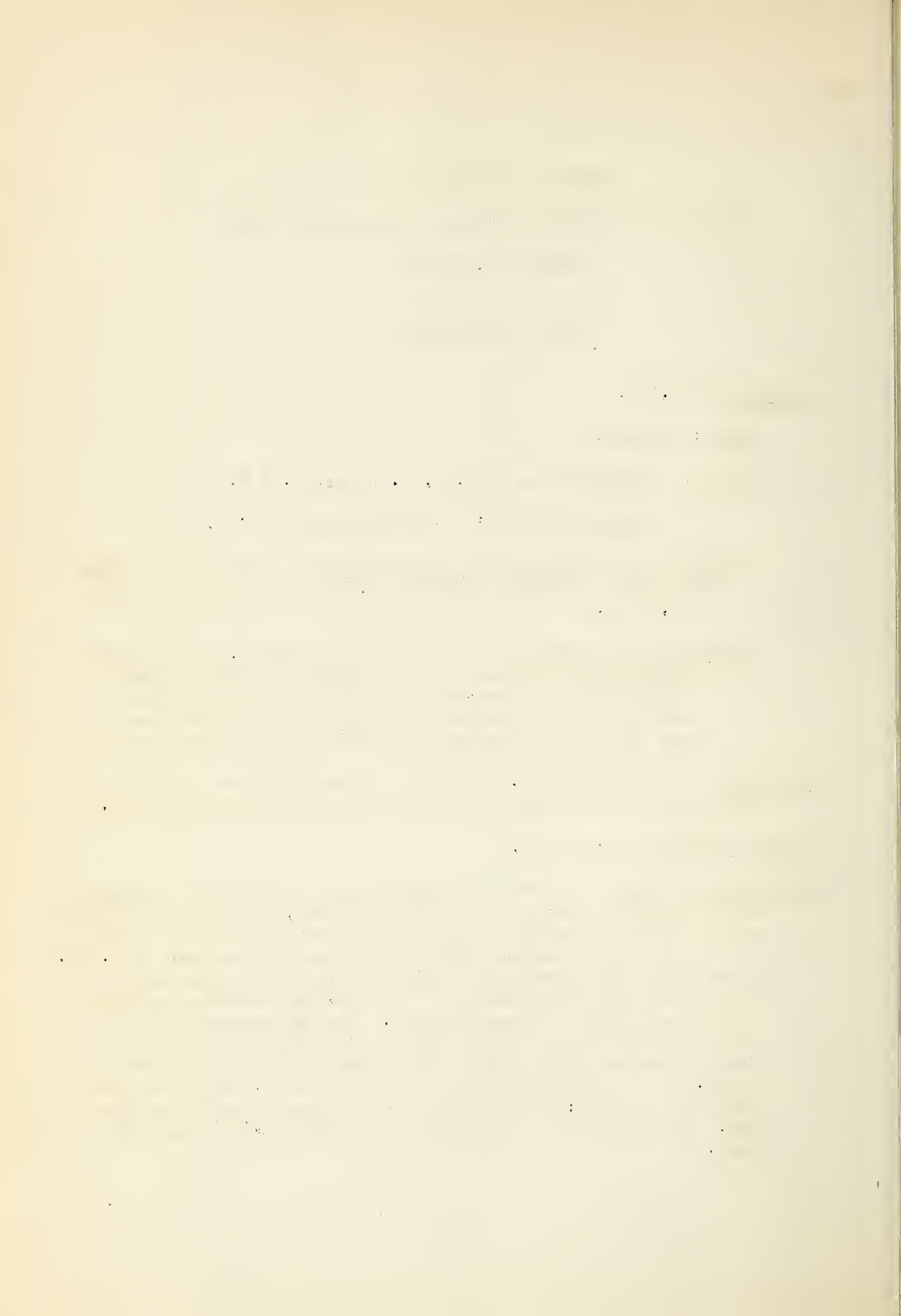
Ownership: State of Kansas. The lake and enclosing State park are administered by the State Forestry, Fish and Game Commission.

Purpose served: Recreation.

Description of dam: The dam is a gravity-type earth-fill structure with an over-all length of about 1,650 feet, a height of 30 feet above the deepest portion of the stream channel, a crest width of 12 feet, and a maximum width at the base of 160 feet (fig. 2). A core wall of wooden sheet piling extends the entire length of the dam and is supplemented by a 200-foot concrete core wall across the original stream channel. The dam extends nearly due west across the valley, except for a length of about 250 feet on the west side, which has a deviation of 61° to the north. The downstream face of the dam has a 2:1 slope and the upstream face a 3:1 slope with a 5-foot berm 8 feet below the top. The slope above the berm is faced with 6-inch concrete slab.

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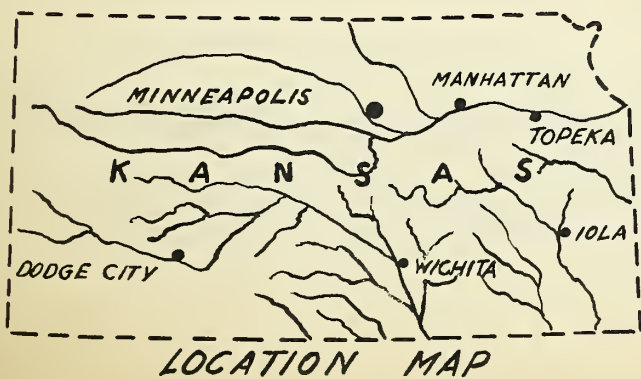
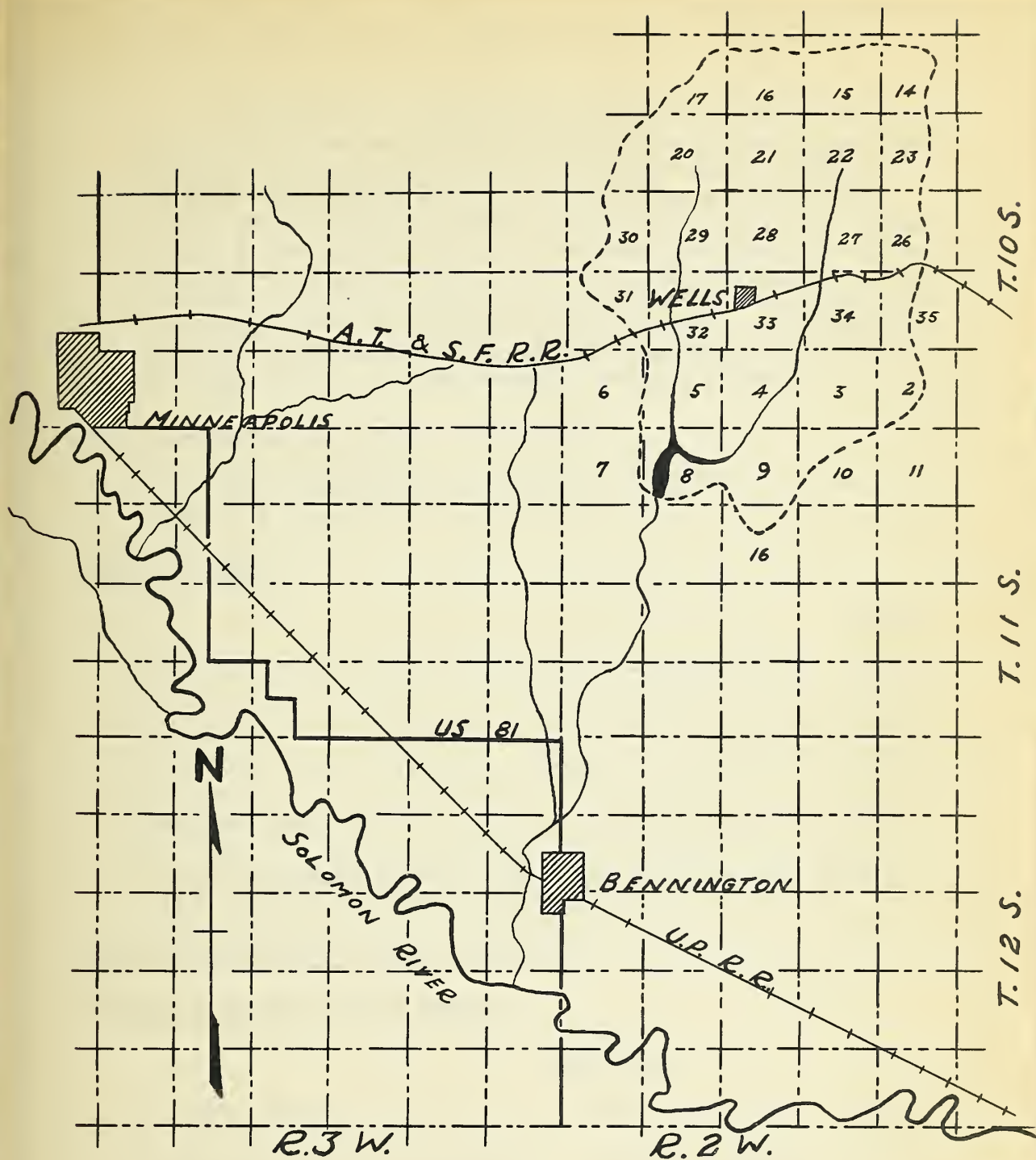


Figure 1  
 LOCATION AND GENERAL  
 RELATION OF  
 OTTAWA CO. STATE LAKE  
 AND ITS WATERSHED  
 WATERSHED BOUNDARY  
 SCALE - 1/2 IN. = 1 MI.



The spillway is near the east end of the dam on the opposite side of the valley from the original stream channel, and consists of a concrete-lined channel through the earth fill in which the sloping sides, lip, and apron are faced with 6-inch concrete slab (fig. 2). Its crest is 200 feet long, and is 6 feet below the top of the dam and approximately 1,321 feet above mean sea level. An outlet, consisting of a 12-inch cast-iron pipe with a gate valve, is located directly over and 2 feet above the original stream channel. This valve was formerly opened at intervals to fill small fish ponds below the dam, but has not been used for several years.

Date of completion of dam: April 1929.

Date of sedimentation survey: April 1937. Age of reservoir: 8 years.

Length of lake:

	<u>Feet</u>
From dam to forks .....	3,400
East arm .....	7,675
West arm .....	4,240
Maximum (dam to head of lake) .....	11,075

There has been no change in the length of the lake at crest stage since the dam was constructed.

Area of lake at crest stage: 134 acres.

Storage capacity at crest stage:

	<u>Acre-feet</u>
Original .....	1,001 (326,175,850 gals.)
Present .....	<u>930</u> (303,040,500 gals.)
Loss due to silting .....	71 ( 23,135,350 gals.)

General character of reservoir basin. Ottawa County State Lake lies in the shallow valley of Sand Creek and is bordered by a smooth gentle slope on the west and by the comparatively steep slope of a sandstone-capped ridge on the east. The two forks of Sand Creek, of which the east fork is the more



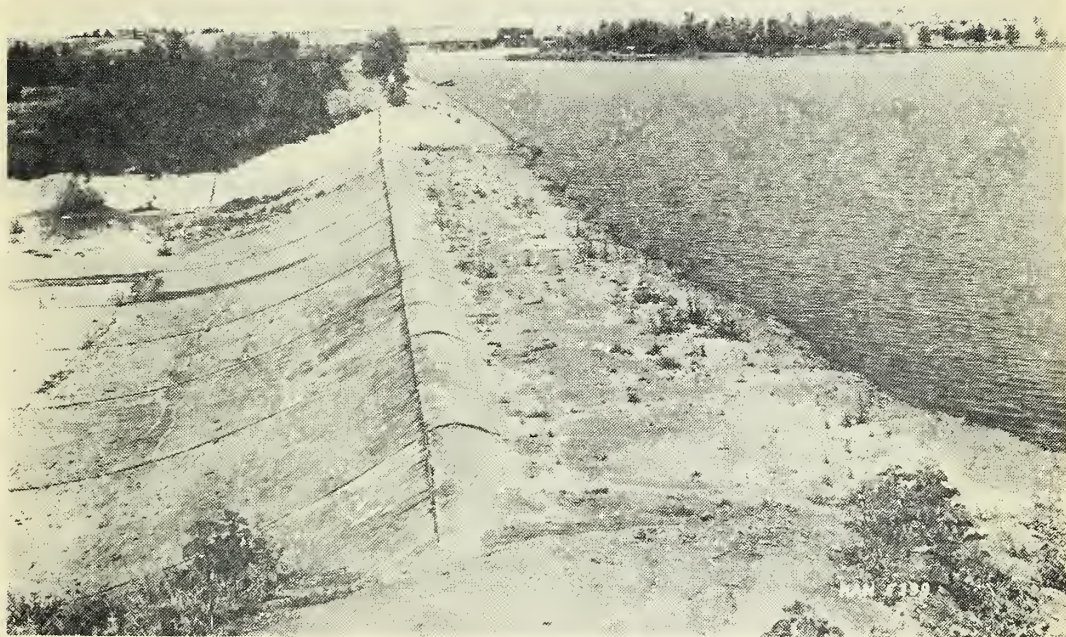


Figure 2.--General view of dam and spillway of the Ottawa County State Lake.



important, join in the flooded area about 3,000 feet upstream from the dam. Below the forks is a broad basin which contains more than three-fourths of the reservoir storage (fig. 4 following p. 10). It is characterized by comparatively straight shore lines and has an average width of approximately 1,300 feet. The two arms of the lake are largely confined to the original channels between vertical stream-cut banks. The average widths of the east and west arms are 175 and 240 feet, respectively.

Sand Creek has an average gradient of approximately 16 feet per mile through the reservoir, and has developed practically no flood plain.

Area of watershed: 20.5 square miles or 13,100 acres.

General character of watershed:

Geology: The watershed of Ottawa County State Lake lies wholly on the outcrop of the Dakota sandstone series. The Dakota formation crops out in Nebraska, Iowa, and north to Canada, as well as at various points in Texas, New Mexico, and along the Rocky Mountains. Over much of this region it is covered by later geologic formations or by glacial or loessial deposits. In northern Kansas, the Dakota formation is exposed, and much of the surface soil is derived from it in a belt 35 miles wide, extending from the northern border of the State, in Washington County, southwest about 125 miles into Rice and McPherson Counties. The Dakota group lies at the base of the upper Cretaceous, and rests unconformably on Permian formations. It is composed of alternating beds of yellow to reddish-brown sandstone, and blue and white shales, and dips 5 to 7 feet per mile to the northwest. In this watershed yellow to brown sandstone, generally poorly cemented, predominates over shale. Concretions of ferruginous sandstone, either hollow or filled with clay, are common.

Topography. The watershed is characterized by low, rolling topography developed on soft shales and friable sandstones. Knolls and ridges, capped by ledges of hard reddish brown sandstone rich in iron oxide, are the most conspicuous topographic features but are not typical of the area as a whole. Slopes average about 5 percent but range from 2 percent on the broad divides and near the streams to 20 percent on knolls and ridges.



Soils. No detailed soil survey of Ottawa County has been made; however the soils of this watershed are reported to resemble the Lancaster soils of Clay County to the east. Like the Lancaster series they are residual soils derived from sandstones and shales of the Dakota group. The A horizon consists of a gray friable sandy loam and averages 1 foot in thickness on gentle slopes that have been left in native grasses. The B horizon is a red to yellow sand containing clay in the interstices or in thin beds, and generally grades downward into beds of disintegrated or fragmented sandstone. The valley soil is similar to that of interstream areas, although it has a higher percentage of sand and organic matter. The land is not very well suited for cultivated crops except on the more gentle slopes and can be more economically used for grazing.

Erosion conditions. Soil losses in the watershed are chiefly the result of sheet erosion, although gullying has occurred to a minor extent in restricted localities. Native grasses provide an excellent cover, and pasture land that has not been overgrazed was in good condition in April 1937. Fields that have been cultivated over a period of years have lost most of an originally thin topsoil. Uncultivated areas once stripped of vegetation have reacted quickly to erosion, and small gullies have formed, particularly in wagon trails and cow paths. Wind erosion is active during some seasons in exposed cultivated fields and to a limited extent on some overgrazed pasture lands.

Little attention has been given to erosion control except by keeping the steeper slopes in grass. Only one farm in the watershed has been terraced.

Land use. In October 1926 the Kansas State Forestry, Fish and Game Commission made a map of the watershed showing its boundaries and the areas of land under cultivation. At that time, 6,260 acres, or 48 percent of the watershed, was under cultivation, mainly in the production of wheat; and 6,840 acres, or 52 percent, was in pasture land. Since then part of the land has been retired from cultivation and it is estimated that at the present time only 40 percent of the watershed is cultivated, and 60 percent is used for pasture. Farming is carried on more extensively in the drainage area of the east fork of Sand Creek, which is about 60 percent under cultivation. The west fork is only 20 percent in cultivation. Wheat is the chief crop although a small acreage is in corn.



There are no native trees in the watershed, but Osage orange (*Toxylon pomiferum*) has been planted extensively in fence rows for windbreaks. The native grass in this region is chiefly buffalo grass, with some gramma and bluestem.

Mean annual rainfall: Average for the period 1889-1930, 25.60 inches, for the period 1929-1936, 22.28 inches (U.S. Weather Bureau station at Minneapolis, Kans.).

### HISTORY OF SURVEY

The sedimentation survey of Ottawa County State Lake was made during the period March 23 to April 13, 1937, by the Section of Sedimentation Studies, Division of Research, Soil Conservation Service. The survey party consisted of Leland H. Barnes, chief, Alvin T. Talley, Alfred J. Kjarsgaard, Richard K. Frevert, and Robert M. Dill, assisted during a part of the work by Mark P. Connaughton and Elliott M. Flaxman.

Original and present capacities and silt volumes were determined by the range method of survey.<sup>1</sup> Horizontal control was established by expanding a triangulation net of six stations from a 1,500-foot base line along the east shore. From these stations and others established by stadia traverse in the two arms 24 silt ranges were located, and the crest contour, 8.2 miles in length, was mapped on a scale of 1 inch to 200 feet. Penetration through the sediment into old soil was successfully accomplished on all ranges by use of the standard spud. The range ends and cut-in stations were marked with metal plates stamped with the station numbers and set in concrete. Elevations of the water surface during the course of the survey were obtained from a recording gage located near the east end of the dam.

The survey of Ottawa County State Lake provides a foundation for much needed studies of the relationship between rainfall and run-off in a watershed which is typical of a large area in the Great Plains. This lake is particularly suitable for measurements of run-off because no water is withdrawn and it rarely overflows.

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<sup>1</sup>Eakin, H. M. Silting of Reservoirs. U. S. Dept. Agr. Tech. Bull. 524: pp. 129-135, 1936.



An automatic gage which keeps a continuous record of the reservoir water level has already been installed by the Kansas Division of Water Resources in cooperation with the United States Geological Survey. A capacity curve, showing the volume of water in the lake at any stage, is being prepared on the basis of soundings taken during this survey. The volume of run-off from any storm will be accurately determined by plotting the water heights before and after the run-off against the capacity curve. Placing of additional rain gages for adequate measurement of precipitation in the watershed and the calibration of the spillway for discharge will complete the requirements for measurement of all factors necessary to determine the ratio of run-off to precipitation.

#### ACKNOWLEDGMENTS

The Soil Conservation Service wishes to acknowledge the assistance of C. R. Dameron, caretaker of the dam and park, during the course of the survey. Murray A. Wilson, civil engineer for the Kansas State Forestry, Fish, and Game Commission, Salina, Kans., loaned original maps of the lake and watershed. E. B. Engle, soil scientist, Soil Conservation Service, Salina, Kans., gave valuable suggestions on watershed conditions. George S. Knapp of the Division of Water Resources supplied information on a large number of lakes in Kansas. F. L. Duley, regional representative of the Research Division, Soil Conservation Service, aided materially in selection of the reservoir and prosecution of the survey.

#### SEDIMENT DEPOSITS

##### Character of sediment

The reservoir sediment is predominantly fine silt and clay, grading in color from grayish black to olive black. Sandy sediment was found in only 3 spud tests near the head of the west arm. In the upper end of the lake, particularly in the west arm, lowering of the water surface has exposed beds of sediment which are marked by the presence of small mud balls resulting from the cracking and curling up of drying surface layers and by the development of yellow streaks in the mass through oxidation.

##### Distribution of sediment

The distribution of sediment in the reservoir is graphically presented in figure 3. Comparison of range lengths, shown in figure 4, will aid materially in discerning the actual distribution of sedi-



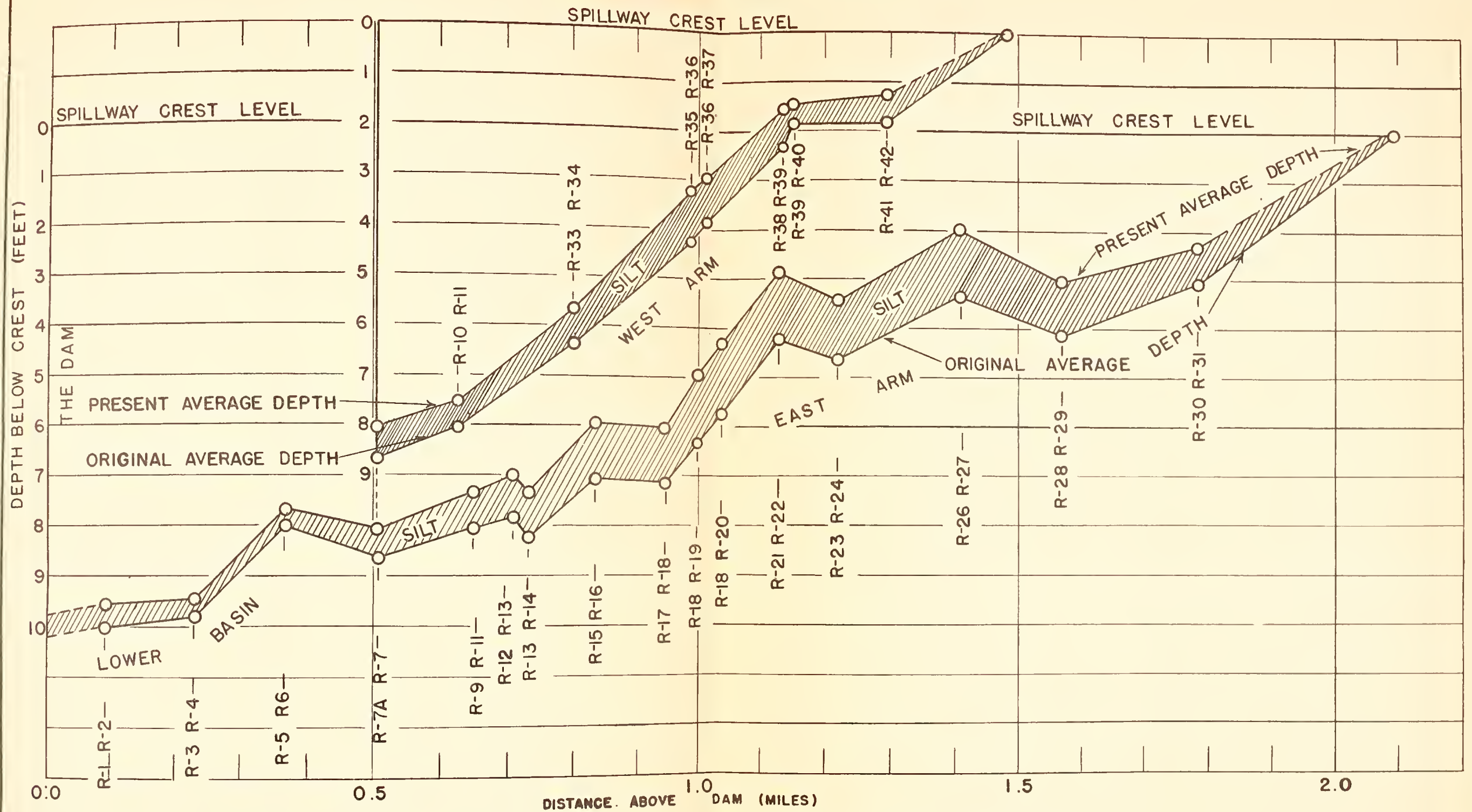


FIGURE 3. AVERAGE DEPTH PROFILE OTTAWA COUNTY STATE LAKE. APRIL 1937



ment. In the lower and main portion of the basin, between the dam and the junction of the two forks, the silt surface tends to conform closely to the original configuration of the bottom. On the gently sloping valley sides the deposit is at all points less than a foot thick, and in the original stream bed it does not average over 2 feet in thickness. In zones extending about 4 feet below crest along the shores of the main basin accumulation has been prevented by wave action and slope wash.

Although exactly half of the reservoir sediment (35.25 acre-feet) has been deposited in the lower 6 segments, the 18 segments within the two arms of the reservoir have lost a much higher percentage of their original capacity. The area between the dam and ranges R9-R11 and R10-R11, which represents 79 percent of the original capacity, has a storage loss of less than 5 percent, whereas the remainder of the reservoir has lost over 16 percent of its capacity.

The unequal distribution of sediment in Ottawa County State Lake has been caused in large part by two closely related factors, namely, the character of the feeder streams and the utilization of the reservoir.

Detailed surveys of many reservoirs by the Soil Conservation Service have shown that in those which bypass a considerable part of the inflow, either over the spillway or through outlets, there is a tendency for sediment to be more concentrated near the dam as a result of the currents which naturally develop.

This lake is fed by small intermittent streams and rarely overflows.<sup>2</sup> Furthermore, only insignificant amounts of water, used to fill fish-breeding ponds below the dam several years ago, have ever been withdrawn through the outlet valve. For these reasons the reservoir has been exceptionally free from currents.

This condition is reflected by the distribution of sediment both as to texture and as to thickness. The texture of the sediment in the upper end is not sufficiently unlike that near the dam to indicate that a gradually retarded current invited the deposition of successively finer sediments. Indications are, rather, that

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<sup>2</sup>This reservoir has overflowed only twice during its history, the greater overflow being in 1932, when the water depth over the spillway was 27 inches.



ponding of water in the upper ends of the two arms had an immediate retarding effect on the feeble stream and permitted deposition of even the finest sediments.

The second determining factor in the distribution of sediment is the exclusively recreational use of the reservoir, as a result of which no water is withdrawn. If the reservoir were used for water supply or irrigation the inflow would be insufficient to sustain the water surface at or near crest. And if the water surface were consistently lowered many feet below crest, the sediment which formed the relatively heavy deposits in the narrow arms would have been carried considerably farther downstream before reaching quiet water.

#### Origin of sediment

The sediment in Ottawa County State Lake has been derived chiefly from sheet erosion of soils developed from the Dakota sandstone series. Inasmuch as these soils are generally sandy in character, and the deposits in the lake are almost free from sand, it is evident that only the finer fractions of the eroding materials, namely, the silts and clays in the topsoil and subsoil, reach the reservoir. It should be noted that this finer material comprises those important constituents, the colloids, silts, and clays, which contain the valuable plant nutrients. Field examinations have shown that heavy sands, which are effectively carried down steep slopes by sheet wash, are dropped as soon as they reach the more gentle slopes near the streams. In certain limited areas, the difference between the almost clean sand at the base of the slopes and the sandy loams higher up is readily apparent. Small washes and gullies are filled with sand of a lighter color than the soil, the finer, darker materials having been removed.

Little sediment is derived from gully erosion as the upland drainage ways are generally covered with a mat of grass. In the lower reaches of the main stream and near the reservoir, however, there appears to be appreciable erosion in the channel. Tree roots are commonly exposed, and the banks have a fresh-cut appearance. The bottom of the channel at intervals is choked with clean, white sand derived from many small gullies and from the stream banks.

Iron oxide, leached from the ferruginous sandstone and soils of the watershed is an important factor in causing the murky, reddish color of the water in the reservoir.



## CONCLUSIONS

The results of this survey, (see p. 10) indicate that, if silting should proceed at the same rate in the future as in the past, Ottawa County State Lake would be completely filled with sediment in 105 years. The reservoir would probably cease to be useful long before this time had elapsed, however, because of loss of adequate depth for swimming, boating, and fishing, and possibly silting-over of sand beaches and development of swampy areas. It is probable, therefore, that under present watershed conditions the useful life of the lake will be nearer 75 than 100 years. On the other hand, this estimate is based on the rate of silting during the period of dominantly subnormal rainfall. With increase of precipitation over a considerable period the rate of storage loss might become appreciably greater and the life period even shorter.

The amount of sediment in the lake and the degree of erosion in its watershed are not as closely related as in reservoirs below watersheds with finer-textured soils. It has been pointed out that the coarser constituents making up the greater part of the soil material have not reached the reservoir, but have been deposited on the lower slopes and in the stream channel above the head of backwater, and that consequently the reservoir sediment consists chiefly of those finer particles which contain the plant nutrients necessary for a productive soil. It is possible, however, that in future years of above-normal precipitation, larger amounts of the coarser debris will be carried down into the reservoir. The amount of erosional debris measured in the reservoir is therefore only a fraction of that eroded from the hillsides in the watershed, although it is by far the most valuable fraction.



The following tabulation is a statistical summary of data relating to Ottawa County State Lake, Bennington, Kans.

	<u>Quantity</u>	<u>Unit</u>
<u>Age:</u> <sup>1</sup> .....	8	Years
<u>Watershed:</u>		
Total area.....	20.5	Square miles.
	13,100	Acres.
<u>Reservoir:</u>		
Original area at crest stage.....	134	Acres.
Present area at crest stage.....	134	Acres.
Original storage capacity.....	1,001	Acre-feet.
Present storage capacity.....	930	Acre-feet.
Original storage per square mile of drainage area.....	48.83	Acre-feet.
Present storage per square mile of drainage area.....	45.37	Acre-feet.
<u>Sedimentation:</u>		
Delta deposits.....	} Not measured separately.	
Bottom-set beds.....		
Total sediment.....	71	Acre-feet.
Accumulation per year, average.....	8.88	Acre-feet.
Accumulation per year per 100 square miles of drainage area.....	43.3	Acre-feet.
Accumulation per year per acre of drainage area.....	29.48	Cubic feet.
Or, assuming average weight of one cubic foot of silt is 100 pounds...	1.47	Tons.
<u>Depletion of storage:</u>		
Loss of original capacity per year...	0.89	Percent.
Loss of original capacity to date of survey.....	7.09	Percent.

<sup>1</sup>Date storage began: April 1929.

Date of this survey: March 23 - April 13, 1937.



Figure 4

